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This report covers visits made to scientific and technical institutes in the USSR and to the Popov Society Congress during 12-28 May 1978. Institutes visited were the Krenkel Central Radio Club (Moscow), Institute of Radioengineering and Electronics of the Academy of Sciences (USSR), A.A. Baikov Institute of Metallurgy (Moscow), Institute of the Problems of Transfer of Information (Moscow), All-union Electrotechnical Communications Institute by Correspondence (Moscow), Television Center (Moscow), TV Tower), Moscow

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State University, Ulyanov (Lenin) Electrotechnical Institute (Leningrad), and the Institute of Cybernetics (Kiev).

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SOME ELECTRICAL AND ELECTRONICS ENGINEERING ACTIVITIES IN THE USSR

This report covers visits made to scientific and technical institutes in the USSR during the period 12-28 May 1978 when I was one of 12 members of an Institute of Electrical and Electronics Engineers (IEEE) delegation participating in a scientific and technical exchange program with the A.S. Popov Scientific-Technical Association for Radio Technology and Electrocommunications (The Popov Society).

In what follows I recount scientific, technical, and cultural aspects of the visits with emphasis on the former two. I try to avoid generalizations, because it must be recognized that only a very limited exposure was possible at each of a very limited number of institutions. The reader would also be well-advised not to attempt to generalize on my observations.

KRENKEL CENTRAL RADIO CLUB (MOSCOW)

Here we were graciously received by Vasily M. Bondarenko (Chief of the Club) and Dr. Kasalsky (who I believe is President of the Radio Sport Federation). The 54 year old Krenkel Central Radio Club is named after the radio pioneer and Hero of the Soviet Union, the late E.T. Krenkel. Some of the latter's equipment, as well as mementos of his arctic exploits, were on display, along with numerous awards received by him and by the club.

There are approximately 26,000 radio amateurs in the USSR compared with 280,000 in the US. Lively communications links exist between these two groups. We toured a room where several attractive young ladies were busily sorting, classifying, and recording mountains of cards of the type radio amateurs exchange to document their contacts. American cards were there in great profusion, and, indeed, in the next several days, I was to learn of warm reunions between Soviet radio amateurs and radio amateurs in our delegation. A highlight of our visit to the Radio Club was the presentation by George Jacobs, leader of our delegation of radio amateur contest awards to those Soviets who earned exceptionally high scores in American contests. A map at the Club showed locations of radio clubs across the entire eleven-time-zone width of the USSR. The only hint of constraints on radio amateur activity was the rather surprising disclosure that the nearest transmitter used by Krenkel Central Radio Club members is situated some 60 km from Moscow.

POPOV SOCIETY CONGRESS (MOSCOW)

The delegation attended two plenary sessions at the Popov Society Congress. These sessions were devoted in part to ceremonial activities and in part to presentations of review papers. Although only limited and intermittent English translation was provided, some super-

ficial understanding of the presentations was nonetheless possible. The first speaker commented on the problems of completing the sequence of difficult steps from electronic research through development and engineering to production, a subject frequently debated in the US and one which apparently knows no East-West political boundaries. The speaker also noted that the task before the Congress was to work out guidelines for the future which were to be presented to the government.

Other speakers treated advanced technologies including microprocessors, microelectronics, bubble memories, Josephson junction (JJ) electronics, and surface acoustic wave (SAW) devices. A highlight was a short presentation by Cosmonaut E.V. Krunov, a very impressive and commanding figure, who expressed appreciation to the Congress for the electronic capabilities they had provided for the space program in the past and at the same time challenged them to greater future accomplishment. Other topics treated in the plenary sessions included the use of radio waves for the study of the atmosphere and the ionosphere, and the use of CO_2 and Nd lasers for treatment of cancer. In the latter instance before and after treatment photos attested to the very impressive success of the medical applications of lasers. It was evident from the breadth of topics covered at the Congress that the interests and concern of the Popov Society extend well beyond radio science and technology.

INSTITUTE OF RADIOENGINEERING AND ELECTRONICS OF THE ACADEMY OF SCIENCES OF THE USSR (MOSCOW)

Our host here was Professor Yuri V. Gulyaev, Deputy Director of the Institute and Head of the Laboratory. Gulyaev is young (forty-ish), impressive, speaks excellent English, is well acquainted in the western world, and has a most engaging personality. The Institute employs 422 people and is housed in serviceable but seemingly old quarters situated quite close to Red Square. Entry to the building is through a security control gate not unlike typical industrial/military secure areas in the US.

Gulyaev discussed two main themes of the laboratory's activity: electromagnetic wave propagation and electronic devices. In the former area interest extends from long waves through the optical region of the spectrum. Attention is devoted to atmospheric and space propagation, active and passive studies of the Earth, planetary atmospheres, and radar studies of planets. In the area of optical fibers attention is focused on graded quartz fibers with losses less than 2 dB/km and on 100-μm-diam. hollow, gas-filled fibers. Data rates of the order of 50 Mbit/sec have been achieved with light emitting diodes and of the order of 500 Mbit/sec with laser sources.

In the area of electronic devices emphasis is on the generation, detection, amplification, and signal processing of electromagnetic waves in the MHz to GHz regions. The effort includes development of SAW devices, and Gulyaev noted that pulse compressions up to 10^4

have been achieved. He also pointed out that, "Surface acoustic wave device production amounted to $300 million in the US last year." The figure appears to me to be grossly high, but then maybe this merely reflects an argument he uses to justify his budget to his management. (A little such amplification in both the Soviet and US parts of this loop might well enhance research budgets in both places, but it isn't likely to attenuate the arms race!) The Institute is also studying sensitive detectors including Josephson junctions and SQUID configurations of Josephson junctions. Noise equivalent powers of 10^{-13} to 10^{-14} W/$\sqrt{Hz}$ were mentioned along with an estimate that 10^{-20} might be attainable in the superheterodyne configuration. Also with regard to detectors, Gulyaev commented that it is possible to make a magnetic-field-tunable maser using the quantum size effect (QSE). QSEs occur when one (or more) specimen dimension becomes comparable to the charge carrier (De Broglie) wavelength. Such effects are expected to play important roles as electronic devices are further microminiaturized. Although the QSE was "discovered" at the Institute of Radioengineering and Electronics, that Institute is just now starting to undertake investigations of inversion layer QSEs in semiconductors, an area that has been actively pursued for many years in the US.

This topic triggered an interesting discussion on the formal meaning of the word "discovery" in the USSR. Gulyaev indicated that discoveries are granted and registered there just as patents are granted and registered. The distinction between discoveries and patents would appear to center on the degree to which the advance is either a new phenomenon or an application of known phenomena. One of Gulyaev's colleagues was quick to point out that discovery number 133 (out of some 150 to date) is the acousto-magneto-electric effect, which was discovered by Gulyaev, who received a monetary prize for his own personal use and of magnitude "sufficient for purchase of an automobile." Another renowned "discovery" is that of the electron-hole liquid in semiconductors.

When queried regarding the funding of the Institute, Gulyaev pointed out that, in addition to the institutional funding base, contract funds are awarded for the performance of specific tasks for industry and development organizations. In spite of this the Institute had recommended in 1964 that industrial organizations should have their own laboratories to short-circuit unwieldy research-development-engineering-production sequences.

Several individual laboratories were toured, and the researches are listed below after the name of the investigator (transliterated to the best of my ability):

Vystavkin is investigating the properties of variable-thickness Dayem bridges (Josephson junctions).

Tsarkin is studying ESR and NMR in superparamagnets. His interests include dynamic nuclear polarization and spin-spin interactions. He uses a microwave pump to increase the paramagnetic susceptibility by as much as a factor of 10^3.

Bascharenov conducts both active and passive remote sensing studies via satellite (0.8-, 1.3-, 3-, 8-cm wavelength) and via aircraft (8 channels from 0.08 to 40 cm). His interests center on depth and condition of Antarctic ice and on temperature and salinity as they relate to radio brightness. He also conducts studies of agricultural crops and of subsoil character. At 2 and 20 cm wavelengths he determines subsoil water down to 2 m in depth.

Persikov has developed equipment for drawing both solid and hollow optical fibers.

Shakovskoi described investigations underway in Katernikov's laboratory, which participated in the scientific investigations of the first Sputnik (1957) and of the Project Luna Moon landing. Using 40-cm wavelength radar sets in the Crimea, they conduct measurements of Venus and Mars to determine surface roughness, rotation rates, and orbital parameters (to an accuracy of 400-500 m).

Vorshilov conducts satellite experiments to determine the nature of the atmospheres and ionospheres of Mars and Venus. Good correlation with Mariner data was obtained. Plasma was detected in the vicinity of the Moon. Plasma occultation studies of the Sun were conducted.

Yjudski and Illiansov are investigating quantum size effects (QSE) in semimetal single crystals. Bismuth crystals of thickness of the order of 1000 Å are grown epitaxially on mica substrates at 10^{-6} Torr. The sizequantized discrete charge carrier energy levels (subbands) are verified by observation at low temperatures of (a) oscillatory dependence of electrical resistivity on thickness, (b) oscillatory behavior of the second derivative of the electron tunneling current-voltage characteristic, and (c) oscillations in the electrical resistivity versus pressure. This last manifestation of QSE is observed at temperatures as high as 77 K.

Stepanov has developed a nonvolatile semiconductor memory device. It makes use of Au-doped n-type Si substrate. Depending upon the magnitude and sign of the voltage applied between an ohmic contact and a Schottky barrier contact, a highly conducting filament is either created or destroyed evidently by melting. Switching is between 1 Ω and 10^6 Ω at 5 to 7 V. Switching time is 10^{-3} to 10^{-6} sec. The device deteriorates after about 10^4 cycles. These are not impressive characteristics as far as memories are concerned, but the device could perhaps find application as a means to disconnect faulty circuits and to connect to functioning replacement circuits in a self-repairing system. Details are published in *Microelectronika* 6, 20 (1977).

Divin and Kogan are developing point contact Josephson junction detectors as wideband radiometers for astronomy studies. Maximum sensitivity is observed at a wavelength of about 2 mm. Noise temperature is about 0.1 K and noise equivalent power is about 10^{-14} W/$\sqrt{\text{Hz}}$.

A.A. BAIKOV INSTITUTE OF METALLURGY (MOSCOW)

Because of my interest in the superconductivity research of a group headed by Dr. E.M. Savitskii, I had requested that the Popov Society arrange a visit to this Institute. I was accompanied by Alexander Ishchenko of the Popov Society, who served as interpreter. Savitskii graciously outlined the very broad scope of interests of his group in metals and alloys with emphasis on the physical properties and applications of refractory, rare earth, and nobel metals and their alloys. Themes include single crystals; phase diagrams; crystal structure; thermal emission; and magnetic, thermal, electrical, and superconducting properties. Very impressive refractory metal single crystals were exhibited. Individual laboratory visits in this Institute were as follows:

Kitrenko has studied superconducting properties of Nb-base materials sintered at high temperatures and high pressures. For Nb_3Ge sintered at 1300 to 1400°C and 70-90 kbar the superconducting transition commenced at 22.3 K. Midpoint of the transition was at 19.7 K.

Kadirbaev is developing explosive techniques as a means to synthesize superconducting materials. Pressures of 10^3 kbar are attained. He hopes to produce Nb_3Si, which, it is widely believed, should have a very high superconducting transition temperature.

Efimov uses rotating copper roller (wringer) fast-quench techniques (10^4 degrees per second) to study the phase diagrams and superconductivity of the ternary alloys Nb-Al-Cu, Nb-Al-Ge, Nb-Ge-Cu and others.

Sumarkov achieves quench rates as large as 10^7 degrees per second with A15 compounds 5 to 100 µm thick. For quenched Nb_3Ga the superconducting onset appeared at 21.2 K and the half resistance at 20.3 K.

Bychkova is studying losses in superconducting Nb-Ti alloy single crystals in oscillating magnetic fields. Largest and smallest losses are observed respectively at compositions of 5.5 and 61 at.% Ti. Extrapolation of such results to highly-strained polycrystalline superconducting magnet cables is not justified, but the studies do not contribute to the general understanding of loss mechanisms.

Savitskii and Gribulia have developed a scheme for predicting the existence of A15 structure materials, i.e., materials for which there is generally believed to be a great probability of finding high superconducting transition temperatures. Atomic data and data on existing A15 compounds are combined in an empirical scheme, and the predictions are used to guide experimental investigations.

Koslova is studying super Schottky detectors formed when a Pb point is brought into contact with GaAs. The experiments appeared to be at an early stage. Rather large variations in sensitivity have been observed for various rinses of the surfaces prior to contact.

Burov is studying thermionic emission as a function of orientation for single crystals of refractory metals in a vacuum of 10^{-10} Torr. In W, for example, the work function ranges from 4.34 to 5.35 V as a function of orientation. Burov's laboratory also contained facilities for simultaneous determinations of electrical resistivity, thermal expansion, and phase transformations, all as functions of temperature. Savitskii expressed the wish for an American scientist on an exchange program to work for a year in this laboratory.

INSTITUTE OF THE PROBLEMS OF TRANSFER OF INFORMATION (MOSCOW)

Ours was the first IEEE Delegation to visit this Institute. It had just recently moved to newly refurbished quarters, and, because of confusion regarding the new address, some members of the delegation were unable to find their way there. Nonetheless, we were greeted very warmly by Dr. Vladimir I. Siforov, Director of the Institute since 1966 and also Chairman of the Popov Society (and thus host for our visit to the USSR).

This Institute, which consists of 12 laboratories, was founded in 1961 and currently employs a staff of 280, mainly mathematicians, physicists, and communications specialists. They conduct research on the transmission, distribution, and processing of information, and there is considerable attention to biological problems. Among the areas of active investigation listed by Siforov were channel capacity, coding, decoding, information processing, imaging, image processing, pattern recognition, artificial intelligence, speech processing, man/machine dialogue, computer network problems (network control, centralized versus distributed), game theory, civil electric power systems, medical information processing, electrical parameters of the heart, mechanisms of the eye (of man and of other biological forms), interactions of cells in layers of the eye, nerve systems, transmission of information from the brain to the "organs of movements," and information transfer in biological cells down to the molecular level.

Some representative accomplishments of the Institute were also mentioned by Siforov. One staff member received the Lenin Prize for his development of an arm prosthesis, and last year two others received state prizes in biology. A six-legged walking machine controlled by a computer and developed by the Institute in collaboration with the Moscow State University Institute of Mechanics was a source of great pride, because it "carried a glass of cognac and didn't spill a drop." (I suspect the machine had no taste for cognac, and it would have been a different story with vodka.)

In one of the laboratories we were treated to a demonstration of computer processing of images of the surface of Mars obtained at an altitude of about 1500 km.

ALL-UNION ELECTROTECHNICAL COMMUNICATIONS INSTITUTE BY CORRESPONDENCE (MOSCOW)

This Institute is a Soviet-style correspondence school, which falls organizationally under the jurisdiction of the University of Communications. Other correspondence schools are situated in Novosibirsk, Tashkent, Odessa, Leningrad, and two other cities, the names of which I failed to record. Our host was Ju B. Zubarev, who is Rector of the Institute. He informed us that the Institute serves 12,000 correspondence students throughout the USSR, preparing them for careers in all phases of communications, including scientific, technical, and economic aspects of radio, television, telegraph, telephone, and the postal system. Some two million people are employed in the post and telecommunications industry in the USSR. The Institute's students are fully employed, but liberal provisions are made by their employers to accommodate their educational activities. The students are served by 250 faculty members, 27 of whom possess the Soviet doctorate degree. (The Soviet kandidat degree is said to be equivalent to the US doctorate, while their doctorate is said to require considerable additional professional accomplishment.)

Although the Institute is basically a correspondence school, there are laboratories, and students do sometimes spend short periods of time on campus. We toured a very well-equipped microwave frequency and radio frequency laboratory, where several students were carrying out experiments, and it appeared to compare favorably with student laboratories in good American universities. We also toured the Institute's computer center, where we saw what appeared to be a modern and businesslike array of computer hardware. We were informed that faculty members perform some R&D in areas such as automatic telephone systems, multiplexing, TV systems, economics, etc.

TELEVISION CENTER (MOSCOW)

This showplace of the State Committee for Radio Broadcasting was the most modern, most luxurious, and largest of the buildings we visited. The building and facilities are most impressive testimony to the very important role assigned to television in conveying government policies and position to the citizenry. We were ushered into a very luxurious room with a conference table that I would estimate was 60 ft long. There a high official provided a short introduction. The 3000-room building has a volume of one million cubic meters and a floor area of 165,000 m^2. The Moscow TV Center provides programs for some 120 TV stations in the USSR, which broadcast in some 70 languages. (Despite the diversity of the republics of the USSR all students are taught Russian "so that language will not bar their access to the more desirable higher education and employment.") I gained the impression that the center runs 8 program phases to accommodate the 11 time zones of the USSR (but I may be confused on this point). All programs are produced in color. The 625-line picture scheme is used and is compatible with the French system.

A brief tour of some of the studios revealed very professional-looking equipment, most of which we were told is of Soviet manufacture. The remainder is purchased from Bosch (West Germany), CSF (France), and Ampex (US).

TV TOWER (MOSCOW)

The TV antenna tower is situated across the street from the TV Center. The chief engineer guided us on a tour of the tower and described its transmitting facilities. The tower rises to a height of 540 m, the top 155-m section of which is devoted to antennas. The tower is constructed of prestressed concrete. In sunlight the deflection from differential thermal expansion amounts to 5.5 m: Deflection from wind forces is 1.5 m. Signals for the 4 local TV channels are provided by 50-kw transmitters for a reception range of 100 to 120 km.

MOSCOW STATE UNIVERSITY (MOSCOW)

About half of the delegation participated in this visit to the Physics Department of Moscow State University. Our hosts were Dr. K.K. Likharev and Dr. Victor F. Petrov. Both are fluent in English and have traveled extensively in the US.

The main entry hall of the physics building is very unlike what one might see in any physics building in the US. A large WWII battle photograph covered one entire wall at the end of the hall, and there were individual photos of the approximately 80 graduates and students of the Department who died in that war. Others who served in the military and survived were pictured at the other end of the hall. Another display chronicled the evolution of the organization chart of the Physics Department from its origins in 1755 to the present. Photos of prominent members of the Department who have received noteworthy state prizes including the Lenin Prize are prominently displayed. It is perhaps needless to say that this display represents a veritable who's who of physics. There is also a photo display, which is changed annually, that honors individuals at all levels (faculty, students, service personnel, etc.) who have been cited for high accomplishment by the Department.

Total enrollment at Moscow State University is 35,000. Of these, 3000 are majoring in physics, which makes this Department the largest in the USSR (and probably in the world). About one-third of the physics majors are female. There are 300 graduate students. Some 500 students are graduated annually from the Physics department. There are 34 "chairs," and the teaching staff totals 1060, including 14 Academicians, 9 Corresponding Members of the Academy of Sciences, and 105 Professors.

Our hosts provided more background on the kinds of academic degrees awarded by the Department. Before entering the university a typical student will have completed 10 years of school (versus 12 in

the US). He spends 6 years majoring in physics and is awarded a Master of Science degree (or its equivalent). We were told that there is no counterpart to our bachelor's degree. Three years of graduate study lead to the "Kandidat" degree, which the Soviets consider to be equivalent to our Ph.D. degree. The title "Doctor" is bestowed later, only after many additional years of highly productive independent research accomplishment.

The Physics Department has six divisions including nuclear physics, astronomy, radio physics, solid state physics, and theoretical physics. Likharev, whose research deals mainly with Josephson junction detectors, is situated organizationally within the Chair of Oscillations, which is a part of the Radio Physics Division. Some of the other research areas included within the Chair of Oscillations are semiconductor lasers, light modulation and scanning, and nonlinear ferroelectrics for microwave parametric amplification. We visited two laboratory rooms where some of Likharev's research is conducted. In one room we witnessed a demonstration of the narrowing and frequency shift of the resonance of a Bi weak-link SQUID (superconducting quantum interference device) as the device was cooled below the superconducting transition temperature. A primitive but effective helium recovery system was in use. In other experiments Likharev is attempting to develop a new microwave SQUID involving a ferroelectric, but he did not elaborate on the concept. In the other laboratory we saw a vacuum evaporator (used for Josephson junction fabrication) which, according to Likharev, was surplus from industry. Incidentally, Likharev has coauthored a book with University of Texas Professor and former ONR Principal Investigator, Bruce Ulrich, who spent a leave of absence in the Soviet Union.

Petrov's interests include semiconductors, microelectronics, magnetism, and magnetic resonance. He expressed interest in the magnetic crosstie memory concept originated by Leonard Schwee at the Naval Surface Weapons Center.

There are about ten small computers in use in the Physics Department. An ES-1010 (said to be equivalent to an IBM-360) is dedicated to nonlinear optics. The Department also has access to two BESM-6 computers at the university computer center.

In addition to institutional funds industrial and government contracts serve as sources for support for Physics Department research.

ULYANOV (LENIN) ELECTROTECHNICAL INSTITUTE (LENINGRAD)

This Institute, founded in 1886, is said to be the oldest in Europe on electrotechnology. Originally the telegraph was the primary interest. The first Rector was Alexander Stepanov Popov, after whom the Popov Society is named. Work on electric power systems began at the institute prior to the revolution, and after the revolution the institute made significant contributions to the development of the plan for the electrification of the USSR. Later in the 30s and 40s, efforts in electric devices and electronics were undertaken.

Some 12,000 students attend the institute, of which 35 to 40% are female. There are more than 1000 faculty members, 120 of whom are professors and doctors of science, and three of whom are corresponding members of the Academy of Sciences. The undergraduate degree requires 5½ years to complete, and is said to be equivalent to a US Masters degree. A year before graduation, students are assigned to other organizations where diploma work is completed. About 85% of the graduates go to industry, the remainder to research institutes. The better students are said to receive offers of 4 to 6 positions. Although a committee ultimately makes the assignments, the wishes of the students weigh heavily in the decisions. The graduate must remain for 3 years in his first assignment, after which he is free to seek another. Beginning pay is 120 to 140 rubles per month ($170 to $200 per month). After 5 years of work every engineer must undertake additional education. Typically this consists of alternating 3 days of work and 3 of schooling for a period of 6 months. He must also complete a research project.

At present there are about 500 foreign students at the Institute. Foreign graduates, numbering about 1500, have come from countries and areas such as Poland, Czechoslovakia, Bulgaria, Hungary, Africa, Asia, Cuba, and South America.

Three fields of general concern to the institute are (a) physics of solids and microelectronics, (b) radio technology (including communications, broadcasting, and television) and (c) the theory of control and calculation technology. We were given brief tours of and discussions on microelectronics, the computer center, medical electronics, and the Popov Museum.

Microelectronics. In the microelectronics area interests include production technology, functional electronics, optical electronics, acoustic electronics, computer-aided design (CAD), MOS and bipolar technologies, testing (built-in testing), and microprocessors. Emphasis is on instruction, research, simple demonstrations, and design. Fabrication is accomplished mainly in collaboration with industries such as Svetlana, Positron, and others. Although ion implantation techniques are taught at the Institute, there are no in-house implantation facilities. However, a very ambitious building program is underway (attesting to the serious intent of the Soviets in this area), and microelectronics processing laboratories are included in this program. Interestingly, the new buildings have much greater aesthetic appeal than is the norm for Soviet architecture.

Our questions regarding current industrial technologies yielded little in the way of information. For example, we were unable to learn what kinds of logic (TTL, ECL, I^2L, etc.) are utilized. We were told, however, that emphasis is on 8 and 16-bit devices for automatic production control, that yields are of the order of a few percent for chips 2 to 6 mm on a side with 5,000 to 12,000 gates, and that 32 and 64-pin packages are used.

Computer Center. A tour of the Institute's computer center revealed an array of computer equipment with ES (EC in Russian) designations of 6012, 6022, and 7022, and Minsk 32. Carl Zeiss (Jena, GDR) magnetic tape units were in evidence. The center is getting a new several-megabyte ES-1065 system, which will accommodate 100 to 200 terminals. Present capability includes 512 K core memory, 600-nsec access time, 1.2-μm cycle time, 200-nsec clock time, and 7 Mbytes of disc memory. FORTRAN and other US computer languages (in English) are used, and we were told there is no interest in converting to the Cyrillic alphabet.

Department of Biomedicine and Protection of Environment. Although this title implies a broader mission, this Department was said by our host, Lenin Prize winner Dr. V.M. Akhutin, to be the first of medical electronics in the Soviet Union. Akhutin's primary interest is the application of electronics to health care delivery for remote regions of the USSR. To illustrate the nature of his work he showed us photos of aspects of the system in operation in the Azerbijian Republic, which is populated by two million people served by one hundred physicians. It is not practical to place a clinic in every village, and so a large center was established in Baku, a large city. In addition to medical facilities the center has at its disposal communications facilities, a computer, ambulances, helicopters, and fixed wing aircraft. The computer is the "brain" of the center, storing medical information, providing consultation information to physicians in remote locations, regulating dispatch of assets, decyphering EKGs, etc. Physicians carry special devices that allow them to digitize medical data near the patient and to transmit the data via telephone or radio. The distortion vulnerability of analog data transmission is thereby avoided. Distance from the most remote village to the center in Baku is approximately 300 km. Pictures of the operating room in Baku revealed a large digital display with digits 4.5 cm high presenting data on temperature, heart rate, respiration rate, etc. The intensive care room features special displays for each bed.

Akhutin noted three areas in which improvements are being sought, viz., (a) communications within the hospital, (b) communications between patient and computer, and (c) galvanic-contact-free sensors for monitoring patients.

Preventive medicine is endorsed and encouraged in the new Soviet constitution. We were shown a photo of an instrument that will be utilized in a preventive medicine program. It answers and records sixteen biological parameters in four minutes and does not require that the patient undress. In the proposed scheme each patient will have a card which stores his medical data. This is inserted into the instrument while his medical parameters are being determined, and any deviations from tolerance are signaled.

In a tour of his laboratories, Akhutin mentioned instruments to be used in training swimmers and in monitoring their performance so as to attempt to predict the probability for their success in the

Olympics. He voiced words to the effect that this would bring victory to the Soviet swimmers—but appeared in fact to be joking about the difficulty of competing with the East Germans, who so dominated swimming in the last Olympics. At the same time Akhutin's very dark and well-cultivated suntan may have been a clue to very serious intent.

The Alexander Stepanov Popov Museum. Soviets refer to him as the father of radio, and this museum contains an interesting collection of his transmitters, receivers, and related memorabilia. In 1895 he achieved communication over a distance of 80 m, extending this in 1899 to 25 miles. On exhibit at the museum is a North American Philadelphia newspaper dated September 11, 1901, that reports Popov's 260-mile wireless link between North America and a ship in the Atlantic. Although Marconi is generally accorded significantly more credit internationally for the overall development of wireless communication, there can be little question that Popov was a very significant contributor.

INSTITUTE OF CYBERNETICS (KIEV)

Our host was Academician Professor Vladimir Shurikhin, whose area of expertise is data processing and management. An incomplete list of other staff members (and their areas) who met with use includes Bumen (data transmission), Romanov (analog/digital converters), Larionov (Secretary, Popov Society), Barun (microprocessors and computers), Kolesnikov (international programs), and Maximov (interpreter and foreign relations). Director of the Institute is Victor Glushkov.

The institute buildings are large and modern, and except for elaborate, variegated hardwood floors, are not unlike the typical large American industrial research laboratory. On the end of one building not far from the main entrance is a large and very attractive mosaic in a modern electronic and computer motif.

In concept and mission the Institute of Cybernetics might be viewed as the Soviet version of IBM Research Laboratories, although marked differences in our social and economic systems preclude any close analogy. The Institute, a part of the Ukrainian Academy of Sciences, employs 4500 personnel, including 50 Professors and 350 at a level said to be equivalent to the US PhD. It consists of a research division (employing 2200) and a special design bureau (employing 2300).

Founded on 16 December 1957, the Institute was originally the Computing Center of the Ukrainian Academy of Sciences. It was given its present name in 1962. Academician S.A. Lebedev, who in 1951 created the first Soviet computer, began the process leading to the establishment of the institute. In 1952 he was transferred to Moscow, however, a small part of his staff remained in Kiev to start the institute. In 1956 Glushkov became the leader. At the time Skurikhin joined the institute in 1958 the staff consisted of 113 people. In the late 50s and early 60s it was very evident that great need existed for the application of computers to many areas of the economy, and the Institute grew rapidly, stabilizing (at least temporarily) in 1973.

In about 1965 the universities began to graduate students trained in computer science. The institute staff is said to be young now and well trained in computer science. The staff is about two-thirds male and one-third female, and most nationalities of the USSR are represented. We were told that most of the programmers are female, while men deal mainly with hardware.

The Institute works closely with the universities, and, indeed, it is currently training 200 graduate students. It publishes 15,000 copies of three journals, viz., *Control Machines and Systems*, *Cybernetics*, and *Automation*. According to Skurikhin the last two are available to the US.

The institute works directly with industry. In fact, some 70% of their funding comes from contracts with that source, the remainder being provided by the state. Some special microcircuits are produced by the institute, but industry in the main supplier. A new microcircuit facility is being built at the institute, and employment in that area will be increased from 200 to 1000.

In 1960 the Institute enjoyed a near monopoly in the computer field, but now industry designs and produces computers, and so the Institute focuses on unique devices. Modest production capability is needed for quick reaction to novel needs. An important area has to do with micro- and mini-computers. For example, a microcomputer was developed and successfully applied to the problem of control of carbon in steel; another was developed to control the quality of the welding process in automobile and aircraft structures; a third is used in a system that checks gastric juices; and a M180 minicomputer is used to automate laboratory measurements. Both MOS and CMOS technologies are employed.

Skurikhin outlined five main research themes as follows:

(1) Theoretical and Economical Cybernetics. This area involves 250 to 300 people, mainly experts in theory, numerical analysis, numerical problems, optimization techniques, theory of automata and algorithms, automation of programs, computer-aided design of computers, and automated design of computers. Glushkov, who received a state award last year, heads this area in addition to directing the Institute. Very difficult problems related to planning the economy are addressed. It is necessary to be concerned with optimization and large data banks. The problems of management of the all-union network of computing centers are of importance inasmuch as a large system is needed "to control the economy." Attempts are being made to make use of American experience, but differences in the socialistic and capitalistic systems preclude general applicability. While there is much in common in the enterprise of single firms, problems arise with the differences at higher levels. The main effort at the Institute has to do with software, inasmuch as the economic models are designed in other institutes. This is a long-range effort, and quick results are not expected.

(2) Creation of Large Data Processing Systems. We were told that the computing center in the Institute of Cybernetics is one of the largest in the Ukrainian Republic. The computers are used for the Institute's research; computing time is "given" to the Academy of Sciences (the computers in some instances being networked with computers in five other institutes); and some computer time is sold to other organizations, "yielding millions of rubles per year." The Institute conducts research on data processing for enterprises and factories. There are 2000 such systems in use in the USSR, many of which were designed at the Institute. In addition to the usual technical questions, psychological problems related to the trade unions were encountered in the introduction of these systems. Computer inquiries are accomplished mainly by telephone, but a special system is being planned for introduction in about 15 years. There is some activity in radio electronic MODEMS. Other interests include housing industry applications of computers.

(3) Computer Engineering. Research in this area includes computer architecture, communication between computers, micro- and minicomputers, A/D converters, and research on physical processes for use in computers.

(4) Technical Cybernetics. This area, which involves about 200 people, includes automatic control of technological operations and physical processing, industrial applications (chemical industry, oil refining), controlled thermonuclear reactions (in collaboration with Americans using Tokamaks), and aircraft traffic control in the vicinity of large airports.

(5) Medicine and Science Policy Studies. The medical area is concerned with application of computers to medical diagnostics, operation of hospitals, and documentation. The science policy effort is concerned with prediction, forecasting, studying science as a process, and attempting to understand the function of individual scientists in science.

A question and answer session with our hosts revealed a number of interesting facts. The Institute's annual budget is 8-10 million rubles. They utilize subcontracts to some extent. Research problems are formulated mainly in house, and these are discussed by a central scientific council from whom approval must be obtained. Higher level approval must be obtained from the Academy of Sciences and a state planning body. The latter may also suggest problems. Many suggestions (theory, experiment, applications) are also received from industry. The Institute cannot respond to all suggestions, and so those that match the capabilities and interests of the staff are selected. It was claimed that staff members have great freedom of selection, and there are no conflicts to speak of, because the ministries and industries "know our interests and skills."

The first five Dneper (?) computers were built at the Institute. Then all documentation was transferred to the manufacturer. Prices are established by a state committee. Before they render a decision they consider pricing suggestions from the manufacturer, the customers, and the institute. The computer is sold at a fixed price, but as the learning curve is followed prices are generally reduced. Factory incomes are controlled and regulated.

We were told that the Soviets, following US practice, have a unified system of computers. They use the American standard for interface devices, and they also have systems with CAMAC (?) or European interfaces. (I don't know whether all of this is internally consistent or not.) Most recent projects utilize 16-bit n-MOS technology.

We toured the display area of the Institute and saw a rather extensive collection of computer peripherals and instruments. They looked very business-like, and in typical trade show fashion, advertising flyers were available (in Russian and other languages) describing performance characteristics. Research activities were also illustrated. I was particularly intrigued by a Josephson junction device display. The square white substrate appeared to be a ceramic about 2 cm on a side. It was labeled 2000 bits and the legend indicated a switching speed of 10^{-11} sec, a factor of 10^4-10^6 less energy required, 10^5 to 10^6 elements per square centimeter, nonvolatile, and low noise at -270°C. I suspect it was a memory and that the performance figures (especially the switching speed) are goals rather than achievements. Our hosts professed ignorance of the details except to say that the effort is under the direction of Professor Genady Mikhailov. In any event, it appears that the Soviets are taking Josephson junction technology seriously.

A visit to the very large (perhaps 100 × 200 ft) computing center revealed a spectrum of gear extending from an old vacuum tube computer through equipment of modest age, to the most modern Soviet hardware. I assumed the vacuum tube model was there for historical reasons—but, nonetheless, it appeared to be operating, blinking lights and all. A small Hungarian Videoton unit was in use, and the ubiquitous East German Carl Zeiss magnetic tape units were busily torquing 3M magnetic Scotch Tape. Maybe, in spite of all evidence to the contrary, it really is just one world!